NORTHWEST CROPS & SOILS PROGRAM

2022 Soybean Cover Crop Termination Trial

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THE UNIVERSITY OF VERMONT EXTENSION

2022 SOYBEAN COVER CROP TERMINATION TRIAL

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In 2022, the University of Vermont Extension Northwest Crops and Soils Program investigated the impact of a winter rye cover crop on soybean crop yield and quality at Borderview Research Farm in Alburgh, VT. Soybeans are grown for human consumption, animal feed, and biodiesel, and can be a useful rotational crop in corn silage and grass production systems. Cereal or winter rye is commonly planted in this region as a cover crop. As soybean production expands throughout Vermont, it is important to understand the potential benefits, consequences, and risks associated with growing cover crops in these systems. To support the local soybean market and to gain a better understanding of cover cropping in soybean production systems, the University of Vermont Extension Northwest Crop and Soils (NWCS) Program, as part of a grant from the Eastern Soybean Board, conducted a trial in 2021-2022 to investigate the impacts of winter rye seeding rates and spring termination methods on the yield and quality of the subsequent soybean crop.

MATERIALS AND METHODS

The trial was conducted at Borderview Research Farm in Alburgh, VT in 2021-2022. The experimental design was a complete randomized block design with split plots and four replications (Table 1). The main plots were three spring cover crop termination methods. See Table 2 for a description of termination treatments. Subplots were four winter rye seeding rates, which included a Control (0 lbs. ac^{-1}), 50, 100, and 150 lbs. ac^{-1} of Gardner winter rye (Albert Lea Seedhouse, MN). The winter rye was planted on 29-Sep 2021. In the spring prior to cover crop termination, ground cover was measured by processing photographs using the Canopeo© smartphone application on 6-May 2022 in the tillage and herbicide treatments and on 23-May 2022 in the plant green treatment. Cover crop biomass was also measured at termination on 6-May 2022 in the tillage and herbicide treatments and on 23-May 2022 in the plant green treatment. A $0.25m^2$ area was harvested using hand clippers and a quadrat from each plot except for the control treatments. Samples were weighed prior to and after drying to determine dry matter content and calculate rye biomass. On 24-May 2022, the soybeans were planted using a 4-row John Deere 1750 four-row planter fitted with bean cups at a rate of 180,000 seeds ac^{-1}. The variety SG 0720XT (maturity group 0.7) soybean was obtained from Seedway, LLC (Hall, NY) for the trial.

Table 1. Trial management details, Alburgh, VT, 2021-2022.

Location	Borderview Research Farm-Alburgh, VT
Soil type	Covington silty clay loam, 0-3% slopes
Previous crop	Corn silage
Plot size (feet)	10 x 20
Row spacing (inches)	30
Replicates	4
Cover crop planting date	29-Sep 2021
Cover crop variety	Gardner winter rye

Cover crop seeding rates (lbs. ac^{-1})	0, 50, 100, 150
Soybean variety	SG 0720XT (maturity group 0.7, Roundup Ready®2Xtend)
Fertilizer	7-18-36 (200 lbs. ac^{-1})
Soybean planting date	24-May 2022
Soybean seeding rate (seeds ac^{-1})	180,000
Soybean harvest date	5-Oct 2022

Table 2. Cover crop termination treatments, Alburgh, VT, 2022.

Treatment	Cover crop termination details
Tillage	Sprayed with Roundup PowerMAX® at 1qt ac^{-1} to terminate then tilled under with a Pottinger Terra Disc one week prior to soybean planting.
Herbicide	Sprayed with Roundup PowerMAX® at 1qt ac^{-1} one week prior to soybean planting.
Plant green	Soybeans were planted into living cover crop and sprayed with Roundup PowerMAX® at 1qt ac^{-1} just following planting.

To determine if the seeding rate or termination of the cover crop had an impact on any soil properties, soil samples were collected from the control and 100 lbs ac^{-1} plots in the tillage and plant green treatments prior to cover crop termination, on 6-May and 23-May 2022 respectively, and were submitted to the Cornell Soil Health Laboratory for the Comprehensive Assessment of Soil Health analysis (Ithaca, NY). Soils were also analyzed for soil Nitrate-N (NO3) content at the UVM Agricultural and Environmental Testing Laboratory in Burlington, VT. Approximately 10 soil cores at a 12" depth within each plot were taken using a soil probe, then immediately dried and transported to the lab for analysis. To understand the nutrient release rates of the winter rye and how this was impacted by seeding rate and termination method, soil samples were collected every two weeks beginning at cover crop termination and ending one month prior to soybean harvest. Soil temperature was monitored throughout the season using Maxim iButton temperature sensors and data logger from Embedded Data Systems, LLC (Lawrenceburg, KY). The temperature sensors and data loggers provide temperature readings every four hours. Soil temperature was only monitored in the control and 100 lbs ac^{-1} treatments of all three termination methods. Soil moisture was measured approximately every other week from the time of cover crop termination, 6-May 2022 for the tillage and herbicide treatments and 23-May 2022 for the plant green treatment, through 13-Sep 2022 using a soil moisture meter. Soybean population was measured on 14-Jul 2022 by counting the number of plants in three 1ft sections per plot. On 5-Oct 2022, the soybeans were harvested using an Almaco SPC50 small plot combine. Seed was weighed for plot yield and tested for harvest moisture and test weight using a DICKEY-John Mini-GAC Plus moisture and test weight meter.

Data were analyzed using the mixed model procedure in SAS (SAS Institute, 1999) with the Tukey-Kramer adjustment, which means that each main effect was analyzed with a pairwise comparison (i.e. 'planting green' statistically outperformed 'tillage termination', 'herbicide termination' statistically outperformed 'tillage termination', etc.). Replications were treated as a random effect, and cover crop seed rate and termination treatments were treated as fixed. Sample date for moisture and Nitrate-N was treated as repeated samples. Treatments were considered different at the 0.10 level of significance. Variations in yield and

quality can occur because of variations in genetics, soil, weather, and other growing conditions. Statistical analysis makes it possible to determine whether a difference among treatments is real or whether it might have occurred due to other variations in the field.

RESULTS

Weather data were recorded throughout the season with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 3). Precipitation was much higher this season than normal. From May-Sep 2022 there was a total of 23.9 inches of rain, 4.6 inches above the 30-year average for that same time frame. Warm temperatures in May were followed by unseasonably cool temperatures in June through September. While May was 2 degrees warmer than normal, June and September were both about 2 degrees cooler than the 30-year average. With the cooler temperatures, there was a total of 2501 accumulated Growing Degree Days (GDDs), which is 47 below the average the 30-year average.

Table 3. Weather data for Alburgh, VT, 2022.

Alburgh, VT	May	Jun	Jul	Aug	Sep
Average temperature (°F)	60.5	65.3	71.9	70.5	60.7
Departure from normal	2.09	-2.18	-0.54	-0.20	-1.99
Precipitation (inches)	3.36	8.19	3.00	4.94	4.40
Departure from normal	-0.40	3.93	-1.06	1.40	0.73
Growing Degree Days (base 50°F)	394	459	674	630	343
Departure from normal	93	-64	-20	-11	-44

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger.
Historical averages are for 30 years of NOAA data (1991-2020) from Burlington, VT.

Impact of Seeding Rate

To determine if the winter rye cover crop had an impact on the soil health indicators compared to a control, soil samples were taken from plots with seeding rates of 0 and 100 lbs ac^{-1} before the cover crops were terminated in the spring. Soil health results can be seen in Table 4. Aggregate stability was statistically greater in the cover crop plots compared to the control. Aggregate stability can be improved by maintaining good soil coverage, which reduces the soil exposure to rain and wind. All other results suggest that there was little impact on soil health in plots with winter rye compared to bare ground plots. Both the treatments had overall score that indicate very high functioning soils.

Table 4. Spring soil health by winter rye seeding rate for Alburgh, VT, 2022.

Seeding rate (lbs. ac^{-1})	Organic matter %	Active carbon ppm	Total carbon %	Total nitrogen %	Aggregate stability %	Available water capacity g/g	Soil proteins N mg/soil g	Soil respiration CO2 mg/soil g	pH	Overall score
0 (Control)	7.17	842	4.80	0.428	32.4[b]	0.257	10.8	0.850	6.91	87.4
100	7.37	801	4.79	0.426	**38.8[a]†**	0.253	10.7	0.863	6.92	88.9
LSD (p=0.10)‡	NS§	NS	NS	NS	4.67	NS	NS	NS	NS	NS
Trial Mean	7.27	821	4.80	0.427	35.6	0.255	10.8	0.857	6.91	88.2

†Within a column, treatments marked with the same letter were statistically similar (p=0.10).
‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

Spring soil coverage differed significantly by winter rye seeding rate (Table 5). All of the seeding rates had spring soil cover that was statistically greater than the control. Soil cover was highest in the 150 lbs ac^{-1} treatment (68.4%) and was not statistically different from the 100 lbs ac^{-1} treatment (60.3%). There were no statistical differences in cover crop biomass or soybean yield between seeding rate treatments. Cover crop yield ranged from 1.38 tons ac^{-1} to 1.61 tons ac^{-1}. Soybean yields ranged from 4436 lbs or 73.9 bu ac^{-1} to 4839 lbs or 80.7 bu ac^{-1} and the trial average was 4634 lbs or 77.2 bu ac^{-1}.

Table 5. Cover crop and soybean harvest characteristics by winter rye seeding rate, Alburgh, VT, 2022.

Seeding rate	Prior to cover crop termination		Soybean harvest			
	Spring soil coverage	Cover crop DM yield	Harvest moisture	Yield at 13% moisture		Test weight
Lbs. ac^{-1}	%	tons ac^{-1}	%	lbs. ac^{-1}	bu. ac^{-1}	lbs. bu^{-1}
0 (Control)	15.7[c]†	--	11.9	4436	73.9	56.9
50	52.2[b]	1.38	**12.4**	4664	77.7	56.6
100	60.3[ab]	1.43	11.9	4596	76.6	56.7
150	**68.4[a]**	**1.61**	11.9	**4839**	**80.7**	**57.0**
LSD (p = 0.10)‡	8.67	NS§	NS	NS	NS	NS
Trial mean	49.2	1.47	12.0	4634	77.2	56.8

†Within a column, treatments marked with the same letter were statistically similar (p=0.10).
‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

Overall, disease ratings were low and there was no statistical difference between treatments for bacterial blight, downy mildew, frogeye leaf spot, or Septoria brown spot (Table 6). Downy mildew infection was the highest this season, with an average rating of 4.33 out of 10 in this trial. This is likely due to the cool and wet conditions this season, ideal for downy mildew infection.

Table 6. Disease rating by winter rye seeding rate, Alburgh, VT, 2022.

Seeding rate	Bacterial blight	Downy mildew	Frogeye leaf spot	Septoria brown spot
lbs ac^{-1}	0-10 scale¥			
0 (Control)	2.25	4.25	0.750	0.083
50	2.17	4.42	0.583	0.000
100	2.17	4.17	0.500	0.167
150	2.17	4.50	0.750	0.083
LSD (p = 0.10) ‡	NS§	NS	NS	NS
Trial Mean	2.19	4.33	0.646	0.083

¥ 0 to 10 scale; rating of 0 = no infection or damage and rating of 10 = 100% infection or damage.
‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

Winter rye seeding rate had very little impact on soil moisture (Table 7). Soil moisture fluctuated throughout the season, with the lowest average moisture on 3-Aug at 13.1%, and highest average moisture on 21-Jun at 24.0%. There had been several large rain events between 23-May and 21-Jun, which likely resulted in the increase in soil moisture.

Soil temperature was recorded throughout the season in the control and 100 lbs ac^{-1} seeding rate plots (Figure 1). This figure provides a visualization of temperature but does not, however, state that these differences are statistically significant. Plots that had no winter rye (control), had slightly warmer soil temperatures earlier in the season. This may be due to the cover crop residue in the herbicide and plant green treatments. By mid-July there were almost no differences in soil temperature between control plots and plots that had rye planted at 100 lbs ac^{-1}.

Table 7. Soil moisture by winter rye seeding rate, Alburgh, VT, 2022.

Seeding rate	Soil moisture							
	6-May€	23-May	21-Jun	7-Jul	3-Aug	15-Aug	29-Aug	13-Sep
(lbs. ac^{-1})	%							
0 (Control)	19.5	23.8	23.7^{b}†	18.5	13.3	16.0	**20.5**	21.7
50	18.2	24.3	22.4^{b}	**17.8**	**12.8**	**15.8**	21.2	**20.9**
100	**16.9**	22.4	22.3^{b}	17.9	13.3	17.3	21.0	21.6
150	18.4	**22.0**	**27.7^{a}**	18.5	**12.8**	16.4	22.1	22.1
LSD (p=0.10)‡	NS§	NS	3.15	NS	NS	NS	NS	NS
Trial Mean	18.3	23.1	24.0	18.2	13.1	16.4	21.2	21.6

€ On 6-May, soil moisture was measured at cover crop termination in the Tillage and Herbicide blocks only.
†Within a column, treatments marked with the same letter were statistically similar (p=0.10).
‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

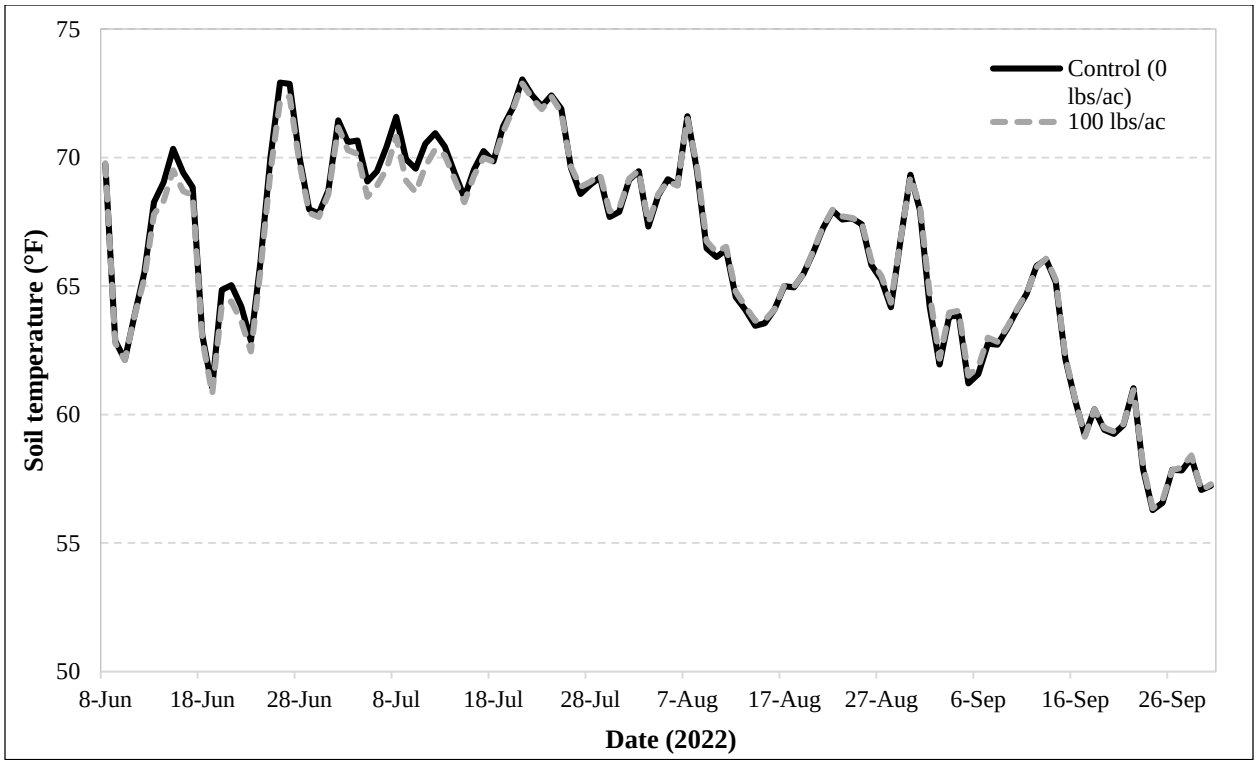

Figure 1. Soil temperature by winter rye seeding rate, Alburgh, VT, 2022.

Impact of Termination Method

Soil health samples were collected just before cover crop termination, which was 6-May for the tillage treatment and 23-May for the plant green treatment, approximately two weeks apart. Active carbon, available water capacity, soil proteins, and overall score were all significantly higher in the plant green treatment (Table 8). Indicating that cover crops can have a significant impact on soil health, especially if terminated at a later stage.

Table 8. Spring soil health by termination method for Alburgh, VT, 2022.

Termination method	Organic matter	Active carbon	Total carbon	Total nitrogen	Aggregate stability	Available water capacity	Soil proteins	Soil respiration	pH	Overall score
	%	ppm	%	%	%	g/g	N mg/soil g	CO2 mg/soil g		
Tillage	6.97	663[b]†	4.40	0.393	36.3	0.244[b]	9.06[b]	0.851	6.92	85.3[b]
Plant green	7.58	**980[a]**	5.19	0.461	34.8	**0.266[a]**	**12.5[a]**	0.862	6.90	**91.1[a]**
LSD (p=0.10)‡	NS§	100	NS	NS	NS	0.014	1.66	NS	NS	2.89
Trial Mean	7.27	821	4.80	0.427	35.6	0.255	10.8	0.857	6.91	88.2

†Within a column, treatments marked with the same letter were statistically similar (p=0.10).
‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

Spring soil coverage and cover crop dry matter yield were significantly impacted by termination method (Table 9). The tillage and herbicide treatments were terminated approximately two and a half weeks before the plant green treatment, and that time allowed for an increase in ground cover and rye biomass. The plant green termination treatment had a spring soil cover (62.3%) and rye dry matter yield (2.61 tons ac^{-1}) that was statistically greater than both other termination methods, but there was no statistical difference between the tillage and herbicide treatments for either metric. Soil cover increased by almost 20% from 6-May to 23-May. Winter rye biomass was 2.4X greater than the herbicide treatment and 3.6X greater than the tillage treatment. Soybean test weight was significantly greater in the plant green treatment, and there was no statistical difference between the other two termination methods.

Table 9. Cover crop and soybean harvest characteristics by termination method, Alburgh, VT, 2022.

Termination method	Prior to cover crop termination		Soybean harvest			
	Spring soil coverage	Cover crop DM yield	Harvest moisture	Yield at 13% moisture		Test weight
	%	tons ac^{-1}	%	lbs. ac^{-1}	bu. ac^{-1}	lbs. bu^{-1}
Tillage	40.4[b]†	0.73[b]	11.9	4545	75.8	56.6[b]
Herbicide	44.8[b]	1.08[b]	12.0	4846	80.8	56.5[b]
Plant green	**62.3[a]**	**2.61[a]**	12.2	4509	75.2	**57.3[a]**
LSD (p = 0.10)‡	7.50	0.427	NS	NS	NS	0.639
Trial mean	49.2	1.47	12.0	4634	77.2	56.8

†Within a column, treatments marked with the same letter were statistically similar (p=0.10).
‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

There was no statistical difference between termination methods for bacterial blight and frogeye leaf spot (Table 10). The plant green treatment had the highest downy mildew score, and that was statistically greater than the tillage and herbicide treatments. The herbicide treatment had the second highest score for downy mildew, and that was also statistically greater than the tillage treatment. The plant green treatment also had significantly greater Septoria brown spot, but there was no statistical difference between the tillage and herbicide treatments.

Table 10. Disease rating by termination method, Alburgh, VT, 2022.

Termination method	Bacterial blight	Downy mildew	Frogeye leaf spot	Septoria brown spot
	0-10 scale¥			
Tillage	2.13	3.00[c]†	**0.875**	0.000[b]
Herbicide	**2.38**	4.38[b]	0.563	0.000[b]
Plant green	2.06	**5.63[a]**	0.500	**0.250[a]**
LSD (p = 0.10) ‡	NS§	0.583	NS	0.195
Trial Mean	2.19	4.33	0.646	0.083

¥ 0 to 10 scale; rating of 0 = no infection or damage and rating of 10 = 100% infection or damage.
†Within a column, treatments marked with the same letter were statistically similar (p=0.10).
‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

There were some significant differences in soil moisture between the termination methods (Table 11). On 6-May when rye in the tillage and herbicide treatments was terminated, the soil moisture was statistically greater in the herbicide block. On 23-May, just before soybean planting, soil moisture was statistically greater in the herbicide and tillage treatments than the plant green treatment, with soil moistures of 24.7, 24.4, and 20.2% respectively. The cover crop in the plant green treatment block had not been terminated yet, and these data suggest that the living winter rye had reduced the available water in the soil. There were no statistical differences in soil moisture on 21-Jun, 3-Aug or 15-Aug. On 7-Jul, soil moisture was significantly greater in the plant green treatment than the tillage treatment but not the herbicide treatment. On 29-Aug and 13-Sep, the herbicide treatment had the greatest soil moisture.

Soil temperature by termination method can be seen in Figure 2. This figure provides a visualization of temperature but does not, however, state that these differences are statistically significant. Soil temperature was similar in all three termination methods over the season. Earlier in the season soil temperature was higher in the tillage treatment, followed by the herbicide treatment, and coolest in the plant green treatment. This trend was likely because there was still cover crop residue, especially in the plant green treatment, and soybean canopy closure had not occurred. By July, soil temperature was similar in the tillage and herbicide treatments and coolest in the plant green treatment. This makes sense because the later termination of the winter rye in the plant green treatment, there was more cover crop residue. By the end of July, there was little difference in soil temperature between the treatments.

Table 11. Soil moisture by termination method, Alburgh, VT, 2022.

Termination method	Soil moisture							
	6-May€	23-May	21-Jun	7-Jul	3-Aug	15-Aug	29-Aug	13-Sep
	%							
Tillage	16.8[b]†	24.4[a]	23.1	16.5[b]	12.8	15.8	21.3[ab]	20.7[b]
Herbicide	**19.7[a]**	**24.7[a]**	23.5	18.9[a]	13.4	16.0	**22[a]**	**22.4[a]**
Plant green	--	20.2[b]	25.5	**19.2[a]**	13.0	17.3	20.4[b]	21.7[ab]
LSD (*p*=0.10)‡	1.22	2.54	NS§	1.98	NS	NS	1.15	1.25
Trial mean	18.3	23.1	24.0	18.2	13.1	16.4	21.2	21.6

€ On 6-May soil moisture was measured at cover crop termination in the Tillage and Herbicide blocks only.
†Within a column, treatments marked with the same letter were statistically similar (p=0.10).
‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

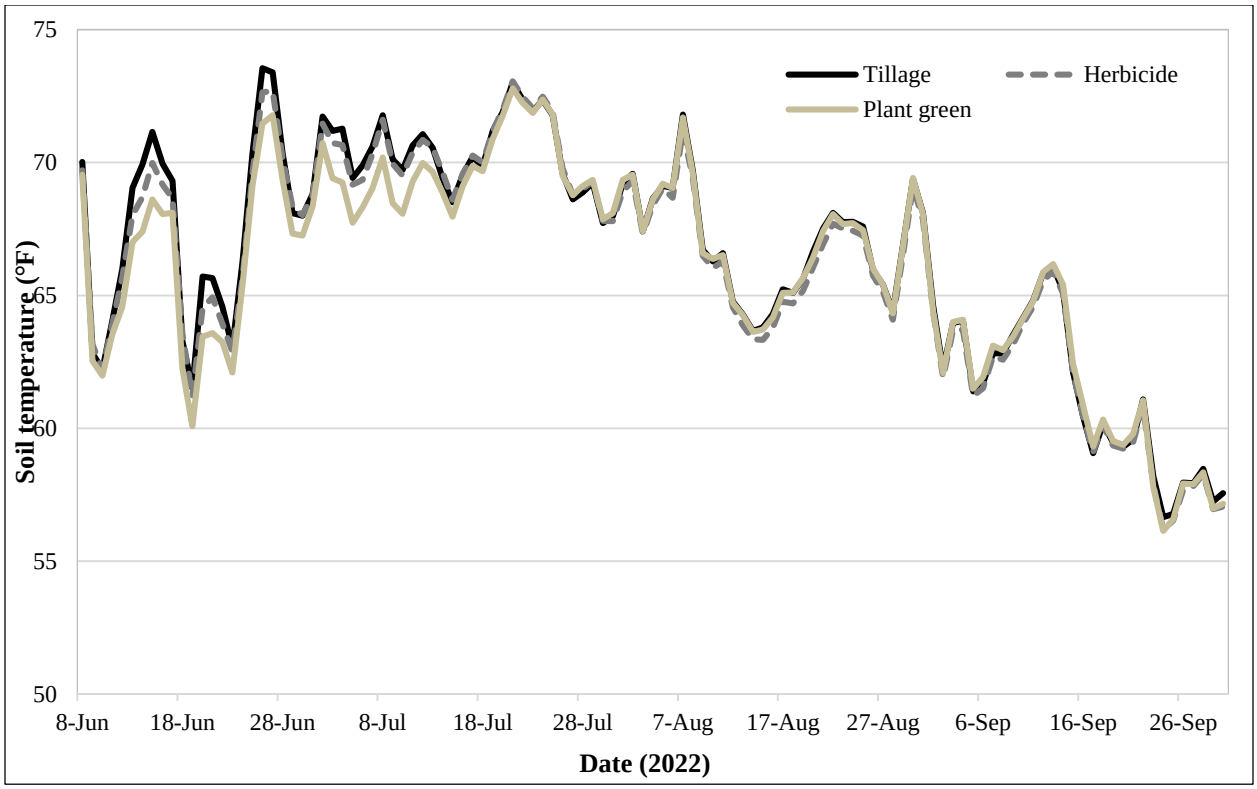

Figure 2. Soil temperature by cover crop termination method, Alburgh, VT, 2022.

DISCUSSION

The 2022 growing season was much wetter than 2021. From May to September 2022 there was an accumulated 23.8 inches of rain, 4.6 more inches than the 30-year average and 10.8 more inches than in 2021 during the same period. Temperatures were cooler than normal from June through September, and that resulted in 2501 accumulated Growing Degree Days (GDDs) (base 50°F), 47 less than the 30-year normal. Soybean yields were good this year and were consistent with other conventional soybean varieties grown at Borderview Research farm in 2022.

Increasing the seeding rate of the winter rye did significantly increase spring ground cover, but it did not lead to a significant difference in rye biomass yield. These results are consistent with what was observed in 2021. Winter rye was planted on 6-Oct 21 and 29-Sep 22. These data suggest that winter rye planted in late September or early October can establish well and produce substantial spring biomass, even when planted at rates as low as 50 lbs ac^{-1}. Planting rye at 2 or 3X the seeding rate did not result in 2 or 3X the quantity of biomass.

There were significant differences in spring ground cover and rye biomass between the termination methods. Cover crop dry matter yield was statistically greater in the plant green treatment than the other two termination methods. These results are like those observed in 2021; the only difference was that in 2021, while the plant green treatment produced the most biomass, it was not statistically different from the herbicide treatment which were terminated about one week apart. This year, the rye was terminated about two and a half weeks later in the plant green treatment. The timing of the cover crop termination likely has

a greater impact on the spring biomass production than the seeding rate or termination method. Soybean yields were not impacted by the cover crop termination method this year, unlike in 2021 where the plant green treatment had statistically lower soybean yields than both the tillage and herbicide treatments, which were not statistically different. In a dry year like 2021, the extra biomass produced when the winter rye was terminated later likely resulted in soybean yield loss due to competition for resources like water because soil moisture was statistically lower in the plant green treatment. Disease pressure in the soybeans was relatively low this season, but downy mildew and Septoria brown spot infections were statistically higher in the plant green treatment. The tillage treatment had a downy mildew rating that was statistically lower than both the herbicide and plant green treatments. The cool, wet conditions of the 2022 season were ideal for downy mildew infection, and it is likely that the addition of winter rye residue in the plant green and herbicide treatments contributed to an increased prevalence of downy mildew infection.

It is important to remember that these data only represent one year and one trial location. Cover cropping can be a beneficial management strategy, but it is important to understand the potential benefits, consequences, and risks associated with growing cover crops in soybean production systems. While cover crop termination method can impact soybean yields, the timing of termination may be even more critical.

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